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Final Technical Report

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Title: A Study of the Solar Wind - Magnetosphere Interaction at the Dayside and Nightside Magnetopause

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Summary of Progress:

(a) Simulation of Driven Fast Magnetic Reconnection

We have carried out a 2-D incompressible MHD simulation study to test the classical theories of fast reconnection. Previous simulations of driven fast magnetic reconnection resulted in a separatrix angle that was much larger than predicted by the theoretical model. The present simulation study is the first time that fast magnetic reconnection has been successfully simulated. The simulation results show that fast reconnection occurs only when the normal component of the magnetic field (B_n) is small (≤ 0.1). In this case, there are four slow shocks attached to the central current sheet and downstream of the separatrices. The current sheet together with the slow shocks accelerate the fluid flow speed to approximately the Alfven speed just upstream of the current sheet through the JxB force, and transfer almost all (>99%) of the frozen-in magnetic energy into kinetic energy. These simulation results are consistent with the analytical theories for small separatrix angles. This project has been completed and the paper is presently in press [*Yan et al.*, 1992].

(b) MHD Studies of Slow Mode Structures in Front of the Dayside Magnetopause

The Interplanetary Magnetic Field (IMF) can pile up in front of the dayside magnetopause, resulting in a plasma density depletion layer. This phenomenon has been predicted by theoretical studies and confirmed by satellite observations. Recently *Song et al.* (1990) reported that in some of the satellite crossings of the magnetopause, the plasma density first increases to a maximum value before decreasing as the solar wind approaches the dayside magnetopause. In this plasma density enhancement region, the magnitude of the magnetic field decreases, which is characteristic of a slow mode wave. We have carried out a 2-dimensional incompressible MHD simulation code to study the slow mode structure locally just in front of the magnetopause. We obtained the slow mode structure similar to the observational result when the x-component of the IMF is present. When $B_x = 0$, the slow-mode structure is not present in the simulation, and only the plasma depletion layer is observed in front of the magnetopause. The paper summarizing these simulation results and supporting theoretical calculations was published in the Geophysical Research Letters [*Lee, Yan, and Hawkins*, 1991].

(c) Slow Shock Results

Slow shocks have been of great interest ever since *Petschek* [1964] proposed a magnetic reconnection model in which magnetic energy was converted to plasma kinetic energy by two pairs of slow shocks. Both the two-fluid hydromagnetic theory [*Coroniti*, 1971] and the particle code simulations [*Swift*, 1983; *Winske et al.*, 1985] of switch-off slow shocks predict the existence of left-hand circularly polarized wave trains downstream of the shock. However, these large amplitude rotational wave trains have not been observed deep in the magnetotail. We have used a 1-D hybrid code to simulate the characteristics of slow shocks as a function of intermediate Mach number, shock normal angle, and plasma beta. Based on these simulations, we have proposed a possible wave damping mechanism to explain the absence of rotational wave trains in the magnetotail. These results have been published in Geophysical Research Letters [*Lin and Lee*, 1991].

(d) Impulsive Plasma Penetration Results

The impulsive plasma penetration model proposed by *Lemaire* [1977] is one possible mechanism by which mass, energy, and momentum from the solar wind might be transferred into the magnetosphere. This model suggests that solar wind irregularities with excess momentum might penetrate through the dayside magnetopause and into the magnetosphere. A theoretical treatment based on ideal MHD theory predicts that penetration will only be possible when the Interplanetary Magnetic Field is aligned with the geomagnetic field [*Schindler* , 1979]. As a first step in studying this process, we have used a 2-dimensional compressible MHD code to investigate the importance of resistivity in the impulsive penetration process. These simulation results showed that impulsive penetration is unlikely when the angle between the magnetic fields exceeds approximately 5°. The results of this study are summarized in 2 papers, one published in the proceedings from the 1990 Cambridge Workshop in Theoretical Geoplasma Physics [*Hawkins, Ma, and Lee*, 1991], and the other published in the Journal of Geophysical Research [*Ma, Hawkins, and Lee*, 1991]. We are in the process of developing 3-D MHD and 2.5-D particle simulations of the the impulsive penetration process.

Publications:

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